ENVIRONMENTAL MONITORING PROGRAM INFORMATION

Introduction

The high-level waste (HLW) presently stored at the West Valley Demonstration Project (WVDP) is the by-product of the reprocessing of spent nuclear fuel conducted during the late 1960s and early 1970s by Nuclear Fuel Services, Inc. (NFS).

Since the Western New York Nuclear Service Center (WNYNSC) is no longer an active nuclear fuel reprocessing facility, the environmental monitoring program focuses on measuring radioactivity and chemicals associated with the residual effects of NFS operations and the Project's high-level waste treatment operations. The following information about the operations at the WVDP and about radiation and radioactivity will be useful in understanding the activities of the Project and the terms used in reporting the results of environmental testing measurements.

Radiation and Radioactivity

Radioactivity is a process in which unstable atomic nuclei spontaneously disintegrate or "decay" into atomic nuclei of another isotope or element. (See *Glossary*.) The nuclei continue to decay until only a stable, nonradioactive isotope remains. Depending on the isotope, this process can take anywhere from less than a second to hundreds of thousands of years.

Radiation is the energy released as atomic nuclei decay. By emitting energy the nucleus moves towards a less energetic, more stable state. The energy that is released takes three main forms: alpha particles, beta particles, and gamma rays.

α *Alpha Particles*

An alpha particle is a fragment of a much larger nucleus. It consists of two protons and two neutrons (similar to a helium atom nucleus) and is positively charged. Alpha particles are relatively large and heavy and do not travel very far when ejected by a decaying nucleus. Alpha radiation, therefore, is easily stopped by a thin layer of material such as paper or skin. However, if radioactive material is ingested or inhaled, the alpha particles released inside the body can damage soft internal tissues because all of their energy is absorbed by tissue cells in the immediate vicinity of the decay.

β *Beta Particles*

A beta particle is an electron that results from the breakdown of a neutron in a radioactive nucleus. Beta particles are small compared to alpha particles, travel at a higher speed (close to the speed of light), and can be stopped by a material such as wood or aluminum less than an inch thick. If beta particles are released inside the body they do much less damage than an equal number of alpha particles. Because they are smaller and faster and have less of a charge, beta particles deposit energy in fewer tissue cells and over a larger volume than alpha particles.

γ *Gamma Rays*

Gamma rays are high-energy "packets" of electromagnetic radiation called photons. They are similar to x-rays but generally have a shorter wavelength and therefore are more energetic than x-rays. If the alpha or beta particle released by the decaying nucleus does not carry off all the energy made available by the nuclear disintegration, the excess energy may be emitted as gamma rays. If the released energy is high, a very penetrating gamma ray is produced that can only be effectively reduced by shielding consisting of several inches of a heavy element, such as lead, or of water or concrete several feet thick. Although large amounts of gamma radiation are dangerous, gamma rays are also used in many lifesaving medical procedures.

Measurement of Radioactivity

The rate at which radiation is emitted from a disintegrating nucleus can be described by the number of decay events or nuclear transformations that occur in a radioactive material over a fixed period of time. This process of emitting energy, or radioactivity, is measured in curies (Ci) or becquerels (Bq).

The curie is based on the decay rate of the radionuclide radium-226 (Ra-226). One gram of Ra-226 decays at the rate of 37 billion nuclear disintegrations per second (3.7×10^{10} d/s), so one curie equals 37 billion nuclear disintegrations per second. One becquerel equals one decay per second.

Very small amounts of radioactivity are sometimes measured in picocuries. A picocurie is one-trillionth (10^{-12}) of a curie or 2.22 disintegrations per minute.

Measurement of Dose

The amount of energy absorbed by the receiving material is measured in rads (radiation absorbed dose). A rad is 100 ergs of radiation energy absorbed per gram of material. (An erg is the amount of energy necessary to lift a mosquito about one-sixteenth of an inch.) "Dose" is a means of expressing the amount of energy absorbed, taking into account the effects of different kinds of radiation. Alpha, beta, and gamma radiation affect the body to different degrees. Each type of radiation is given a quality factor that indicates the extent of human cell damage it can cause compared with equal amounts of other ionizing radiation energy. Alpha particles cause twenty times as much damage to internal tissues as x-rays, so alpha radiation has a quality factor of 20 compared to gamma rays, x-rays, or beta particles, which have a quality factor of 1.

The unit of dose measurement to humans is the rem (roentgen equivalent man). Rems are equal to the number of rads multiplied by the quality factor for each type of radiation. Dose can also be expressed in sieverts. One sievert equals 100 rem.

Environmental Monitoring Program Overview

Human beings may be exposed to radioactivity primarily through air, water, and food. At the WVDP all three pathways are monitored, but air and surface water pathways are the two major means by which radioactive material can move off-site.

The geology of the site (kinds and structures of rock and soil), the hydrology (location and flow of surface and underground water), and meteorological characteristics of the site (wind speed, patterns, and direction) are all considered in evaluating potential exposure through the major pathways.

More detailed measurements are also made for specific radionuclides. Strontium-90 and cesium-137 are measured because they are normally present in WVDP waste streams. Radiation from other important radionuclides such as tritium or iodine-129 are not sufficiently energetic to be detected by gross measurement techniques, so these must be analyzed separately using methods with greater sensitivity. Heavy elements such as uranium, plutonium, and americium require special analysis to be measured because, in comparison to background, they exist at such low levels at the WVDP. The radionuclides monitored at the Project are those that might produce relatively higher doses or that are most abundant in air and water effluents. Because sources of radiation at the Project have been decaying for more than twenty years, the monitoring program does not routinely include short-lived radionuclides, i.e., isotopes with a half-life of less than two years, which would have only 1/1,000 of the original radioactivity remaining. (See *Appendix A* for a schedule of samples and radionuclides measured and *Appendix B* for related Department of Energy protection standards.)

Ionizing Radiation

Radiation can be damaging if, in colliding with other matter, the alpha or beta particles or gamma rays knock electrons loose from the absorber atoms. This process is called ionization, and the radiation that produces it is referred to as ionizing radiation because it changes a previously electrically neutral atom, in which the positively charged protons and the negatively charged electrons balance each other, into a charged atom called an ion. An ion can be either positively or negatively charged. Various kinds of ionizing radiation produce different degrees of damage.

The on-site and off-site monitoring program at the WVDP includes measuring the concentration of solids containing alpha and beta radioactivity, conventionally referred to as "gross alpha" and "gross beta," in air and water effluents. Measuring the total alpha and beta radioactivity from key locations, which can be done within a matter of hours, produces a comprehensive picture of on-site and off-site levels of radioactivity from all sources. In a facility such as the WVDP, frequent updating and tracking of the overall levels of radioactivity in effluents is an important tool in maintaining acceptable operations.

Data Reporting

Because no two samples are exactly the same, statistical methods are used to decide how a

Potential Effects of Radiation

The biological effects of radiation can be either somatic or genetic. Somatic effects are restricted to the person exposed to radiation. For example, sufficiently high exposure to radiation can cause clouding of the lens of the eye or loss of white blood cells.

Radiation also can cause chromosomes to break or rearrange themselves or to join incorrectly with others. These changes may produce genetic effects and may show up in future generations. Radiation-produced genetic defects and mutations in offspring of an exposed parent, while not positively identified in humans, have been observed in some animal studies.

The effect of radiation depends on the amount absorbed. An instantaneous dose of 100-200 rem (1-2 Sv) might cause temporary effects such as vomiting but usually would have no long-lasting side effects. At 50 rem (0.5 Sv) a single instantaneous dose might cause a reduction in white blood cell count.

Assessing biological damage from low-level radiation is difficult because other factors can cause the same symptoms as radiation exposure. Moreover, the body apparently is able to repair damage caused by low-level radiation.

The effect most often associated with exposure to relatively high levels of radiation appears to be an increased risk of cancer. However, scientists have not been able to demonstrate with certainty that exposure to low-level radiation causes an increase in injurious biological effects, nor have they been able to determine if there is a level of radiation exposure below which there are no biological effects.

Background Radiation

Background radiation is always present and everyone is constantly exposed to low levels of such radiation from both naturally occurring and manmade sources. In the United States the average total annual exposure to this low-level background radiation is estimated to be about 360 millirem (mrem) or 3.6 millisieverts (mSv). Most of this radiation, approximately 300 mrem (3 mSv), comes from natural sources. The rest comes from medical procedures and from consumer products.

Background radiation includes cosmic rays, the decay of natural elements such as potassium, uranium, thorium, and radon, and radiation from sources such as chemical fertilizers, smoke detectors, and televisions. Actual doses vary depending on such factors as geographic location, building ventilation, and personal health and habits.

particular concentration compares with concentrations from similar samples. The term *confidence level* is used to describe the range of concentrations above and below the test result within which the "true" value can be expected to lie, at a specified degree of statistical certainty. The WVDP environmental monitoring program uses the 95% confidence level.

The uncertainty range is the expected range of values that account for random nuclear decay and small measurement process variations. The uncertainty range around a concentration is indicated by the plus-or-minus (±) value following the result (e.g., 5.30±3.6E-09 μCi/mL, with the exponent of 10^{-9} expressed as "E-09." Expressed in decimal form, the number would be 0.0000000053±0.0000000036 μCi/mL). Within this range a result will be "true" 95% of the time. For example, a value recorded as 5.30±3.6E-09 μCi/mL means that 95% of the time the "true" value for this sample will be found between 1.7E-09 μCi/mL and 8.9E-09 μCi/mL.

If the uncertainty range is greater than the value itself (e.g., 5.30±6.5E-0 μCi/mL), the result is below the detection limit. The values listed in tables of radioactivity measurements in the appendices include both the value and uncertainty regardless of the detection limit value. If the uncertainty range is greater than the value itself, measurements of radiological parameters may be represented by a "less than" ("<"). Chemical data are expressed by the detection limit prefaced by a "<" if no analyte was measured. Also see **Data Reporting** in *Chapter 5, Quality Assurance*.

In general, the detection limit is the minimum amount of constituent or material of interest detected by an instrument or method that can be distinguished from background and instrument noise. Thus, the detection limit is the lowest value at which a sample result shows a statistically positive difference from a sample in which no constituent is present.

1994 Changes in the Environmental Monitoring Program

Minor updates to the 1994 monitoring program improved the environmental sampling network and supported current site characterization activities. The changes included upgrading air effluent monitoring points, increasing or decreasing selected analytes at specific locations, and upgrading sample collection protocol at the northeast surface water drainage point WNSWAMP.

Major program changes in 1994 included adding analytes to water effluent monitoring in response to two SPDES permit revisions, one in February and another in November 1994. The new wastewater treatment facility, completed in 1994, replaced the old sewage treatment plant and altered sampling requirements for effluent water and sludge.

Appendix A summarizes the program changes and lists the sample points and parameters measured in 1994.

High-level Waste Treatment

Waste from NFS operations was originally stored in two of four underground tanks (tanks 8D-2 and 8D-4). The waste in 8D-2, the larger of the active tanks, had settled into two layers: a liquid – the supernatant – and a precipitate layer on the tank bottom – the sludge.

To solidify the high-level waste, WVDP engineers designed and developed a process of pretreatment and vitrification.

Supernatant Pretreatment

The supernatant was composed mostly of sodium and potassium salts dissolved in water. Radioactive cesium in solution accounted for more than 99% of the total fission products in the supernatant. During pretreatment, sodium salts and sulfates were separated from the radioactive constituents in both the liquid portion of the high-level waste and the sludge layer in the bottom of the tank.

Pretreatment of the supernatant began in 1988. A four-part process, the integrated radwaste treatment system (IRTS), reduced the volume of the high-level waste needing vitrification by producing low-level waste stabilized in cement.

- The supernatant was passed through zeolite-filled ion exchange columns in the supernatant treatment system (STS) to remove more than 99.9% of the radioactive cesium.

- The resulting liquid was then concentrated by evaporation in the liquid waste treatment system (LWTS).

- This low-level radioactive concentrate was blended with cement in the cement solidification system (CSS) and placed in 269-liter (71-gal) steel drums. This cement-stabilized waste form has been accepted by the NRC.

- Finally, the steel drums were stored in an on-site aboveground vault, the drum cell.

Processing of the supernatant was completed in 1990. Eighty percent of the radioactivity in the liquid was removed and more than 10,000 drums of cemented waste were produced.

Pre-Vitrification Activities

The sludge that remains is composed mostly of iron hydroxide. Strontium-90 accounts for most of the radioactivity in the sludge.

Pretreatment of the sludge layer in high-level waste tank 8D-2 began in 1991. Five specially designed 50-foot-long pumps were installed in the tank to mix the sludge layer with water in order to produce a uniform sludge blend and to dissolve the sodium salts and sulfates that would interfere with vitrification. After mixing and allowing the sludge to settle,

Derived Concentration Guides

A derived concentration guide (DCG) is defined by the DOE as the concentration of a radionuclide in air or water that, under conditions of continuous exposure by one exposure mode (i.e., ingestion of water, submersion in air, or inhalation), for one year, would result in an effective dose equivalent of 100 mrem (1 mSv) to a "reference man." These concentrations (DCGs) are considered screening levels that enable site personnel to review effluent and environmental data and to decide if further investigation is needed.

DOE Orders require that the hypothetical dose to the public from facility effluents must be estimated using specific computer codes. (See Chapter 4.) The DCGs are used as a guideline to limit the dose that any individual could receive under extreme (unrealistic) conditions.

The actual calculated dose to the maximally exposed off-site individual from WVDP releases is orders of magnitude less than the 100 mrem DCG standard. Dose estimates are based on a sum of isotope quantities released and the dose equivalent effects for that isotope. In a similar manner, percentages of the DCGs for all radionuclides present are added: if the total percentage of the DCGs is less than 100, then the effluent released is in compliance with the DOE guideline.

Although DCGs for airborne radionuclides are given, the DOE applies the more stringent U.S. EPA NESHAPs standards to airborne effluents.

As a convenient reference point, comparisons with DCGs are made throughout this report for both air and water samples.

processing of the wash water through the integrated radwaste treatment system began. Processing removes radioactive constituents for later solidification into glass, and the wash water containing salts is then stabilized in cement.

1994 Activities at the West Valley Demonstration Project

Pre-Vitrification Activities

Sludge washing was completed in 1994 after approximately 765,000 gallons of wash water had been processed. About 8,000 drums of cement-stabilized wash water were produced. In all, through the supernatant treatment process and the sludge wash process, more than 1.3 million gallons of wash water had been processed by the end of 1994, producing a total of more than 18,000 drums of cemented low-level waste.

As one of the final steps preceeding vitrification, the ion-exchange material used in the integrated radwaste treatment system (IRTS) to remove radioactivity will be blended with the washed sludge in the glass-forming feed mixture.

A single reprocessing campaign of a special fuel containing thorium was conducted by the previous facility operators from November 1968 to January 1969. In preparation for vitrification, the high-level waste from this campaign was transferred into the underground storage tank holding the rest of the sludge. The transfer took place between late 1994 and January 1995. The high-level waste from this campaign will be added to the WVDP vitrification feed mixture.

Solidification into glass is scheduled to begin in 1996. The high-level waste mixture of sludge and zeolite from the ion-exchange process will be combined with glass-forming chemicals, fed to a ceramic melter, heated to approximately 2,000°F, and poured into stainless steel canisters. Approximately 300 stainless steel canisters, 10 feet long by 2 feet in diameter, will be filled with a uniform, high-level waste glass that will be suitable for eventual shipment to a federal repository.

Several major milestones have been reached in completing the Project's vitrification facility. Nonradioactive testing of a full-scale vitrification system was conducted from 1984 to 1989. In 1990 all vitrification equipment was removed to allow installation of shield walls for fully remote radioactive operations. The walls and shielded tunnel connecting the facility to the former reprocessing plant were completed in 1991.

The slurry-fed ceramic melter was fully assembled, bricked, and installed in 1993. In addition, the cold chemical building was completed, as was the sludge mobilization system that will transfer high-level waste to the melter. This system was fully tested in 1994. A number of additional major systems components also were installed in 1994: the canister turntable, which positions the vessels as they are filled with molten glass; the submerged bed scrubber, which cleans gases produced by the vitrification process; and the transfer cart, which moves filled canisters to the storage area. The canister load-in facility design was completed, construction was started, and the computer system controlling overall vitrification operations was programmed.

Low-level Waste Processing

Aqueous Radioactive Waste

Water containing added radioactive material from site cleanup operations is collected and treated in the low-level liquid waste treatment facility (LLWTF). (Water from the sanitary system, which does not contain added radioactive material, is managed in a separate system.)

The treated process water is held, sampled, and analyzed before it is released through a State Pollutant Discharge Elimination System (SPDES)-permitted outfall. In 1994, 44.7 million liters (11.8 million gal) of water were treated in the LLWTF and released through the lagoon 3 weir.

The discharge waters contained an estimated 55 millicuries of gross alpha plus gross beta radioactivity. Comparable releases during the previous eight years averaged about 43 millicuries per year. The 1994 release was about 28% above this average. (See **Radioactivity Concentrations On-site: Low-level Waste Treatment Facility** in *Chapter 2, Environmental Monitoring*.)

Approximately 1.03 curies of tritium were released in WVDP liquid effluents in 1994.

Non-Aqueous Radioactive Waste

In 1994, 763 liters (202 gal) of low specific activity radioactive waste oil was sent to Scientific Ecology Group in Oak Ridge, Tennessee for processing.

Solid Radioactive Waste

Low-level radioactive waste at the WVDP, stored in aboveground facilities, consists of various materials generated through site maintenance and cleanup activities. Metal piping and tanks are cut up and packaged in a special size-reduction facility, and dry compressible materials such as paper and plastic are compacted to reduce waste volume. For more details see the *Environmental Compliance Summary: Calendar Year 1994.*

Airborne Radioactive Emissions

Air used to ventilate the facilities where radioactive material cleanup processes are operated is passed through filtration devices before being emitted to the atmosphere.

Ventilated air from the various points in the IRTS process (high-level waste sludge treatment, main plant and liquid waste treatment system, cement solidification system, and the LLWTF) and other waste management activities centered in the main plant building is sampled continuously during operation. In addition to monitors that alarm if radioactivity increases above preset levels, the sample media is analyzed in the laboratory for the specific radioisotopes that are present in the radioactive materials being handled.

Air emissions in 1994, primarily from the main plant ventilation, contained an estimated 0.04 millicuries (mCi) of gross alpha plus gross beta radioactivity. This compares to less than 0.03 mCi of combined gross alpha and beta activity in 1993 and 0.02 mCi in 1992 and reflects current processing operations. See *Chapter 2, Environmental Monitoring*, for more detail.

Approximately 0.04 curies of tritium (as hydrogen tritium oxide [HTO]) were released in facility air emissions in 1994.

Waste Minimization Program

The WVDP formalized a waste minimization program in 1991 to reduce the generation of low-level waste, mixed waste, and industrial waste. By using source reduction, recycling, and other techniques, waste in all of these categories except hazardous waste was reduced. In 1994, the fourth year of the program, reductions in low-level radioactive waste, radioactive mixed waste, and industrial waste exceeded the 1993 reduction by more than 10%. For more details see the *Environmental Compliance Summary: Calendar Year 1994.*

Pollution Prevention Awareness Program

The WVDP's pollution prevention awareness program is a significant part of the Project's overall waste minimization program. The program includes hazard communication training and new employee orientation that provides information about the WVDP's Industrial Hygiene and Safety Manual, environmental pollution control procedures, and the Hazardous Waste Management Plan.

The WVDP's goal is to make all employees aware of the importance of pollution prevention both at work and at home.

1994 National Environmental Policy Act (NEPA) Activities

Under the National Environmental Policy Act, the Department of Energy is required to consider the overall environmental effects of its proposed legislative actions or proposed federal projects. The President's Council on Environmental Quality established a screening system of analyses and documentation that requires each proposed action to be categorized according to the extent of its potential environmental effect. The levels of documentation include categorical exclusions (CXs), environmental assessments (EAs), and environmental impact statements (EISs).

Categorical exclusions evaluate and document actions that will not have a significant effect on the environment. Environmental assessments evaluate the extent to which the proposed action will affect the environment. If a proposed action has the potential for significant effects, an environmental impact statement is prepared that describes proposed alternatives to an action and explains the effects.

Vitrification Phase NEPA Activities

NEPA activities at the WVDP generally involve facility maintenance and minor projects that support high-level waste vitrification. Most of these projects are documented and submitted for approval as categorical exclusions although environmental assessments are occasionally necessary. (See the *Environmental Compliance Summary* for a discussion of specific NEPA activities in 1994.)

Decommissioning Phase NEPA Activities

In December 1988 the DOE published a Notice of Intent to prepare an environmental impact statement for the completion of the WVDP and closure of the facilities at the WNYNSC. The environmental impact statement will describe the potential environmental effects associated with Project completion and various site closure alternatives. Completion and closure are decommissioning phase activities. In contrast, vitrification phase activities were described in a 1982 environmental impact statement.

In order to assess potential effects associated with alternative closure actions, an extensive multidisciplinary characterization of the site was necessary. Characterization activities began in 1989 and required data collection for several years. Site characterization studies include investigations in geomorphology, soils, geohydrology, surface water hydrology, geochemistry, water quality, air quality, seismology, demography, cultural resources, botany, and terrestrial and aquatic ecology. Many of these studies were completed in 1992.

In late 1992 the DOE selected an independent contractor, Science Applications International Corporation, to prepare the environmental impact statement for closure or long-term management of the WNYNSC. The draft EIS, which evaluates proposed actions and alternatives for the decontamination, decommissioning, and closure of the facilities at the WNYNSC, was being prepared in 1994.

On-site Environmental Training

The occupational safety of personnel who are involved in hazardous waste operations is protected by standards promulgated under OSHA. This act is a comprehensive law governing diverse occupational hazards such as electrical safety and protection from fire as well as the handling of hazardous materials. The purpose of OSHA is to maintain a safe and healthy working environment for employees.

OSHA 29 CFR 1910.120, Hazardous Waste Operations and Emergency Response, requires that employees at treatment, storage, and disposal facilities, who may be exposed to health and safety hazards during hazardous waste operations, receive training appropriate to their job function and responsibilities. The WVDP Environmental, Health, and Safety training matrix identifies the specific training requirements for affected employees.

The WVDP provides the standard twenty-four-hour hazardous waste operations and emergency response training. (Emergency response training includes controlling contamination to groundwater and spill response measures.) Training programs also contain information on waste minimization and pollution prevention. Besides this standard training, employees working in radiological areas receive additional training on subjects such as understanding radiation and radiation warning signs, dosimetry, and respiratory protection. In addition, specific qualification standards for specific job functions at the site are required and maintained. These programs have evolved into a comprehensive curriculum of knowledge and skills necessary to maintain the health and safety of employees and ensure the continued environmental compliance of the WVDP.

The WVDP maintains a hazardous materials team that is trained to respond to spills of hazardous materials. This team maintains its proficiency through classroom instruction and scheduled training drills.

Any person working at the WVDP that has a picture badge receives general employee training covering health and safety, emergency response, and environmental compliance issues.

All visitors to the WVDP also receive a site-specific briefing on safety and emergency procedures before being admitted to the site.

Self-Assessment

Self-assessments continued to be conducted regularly in 1994 to review the management and effectiveness of the WVDP environmental protection and monitoring programs. Results of these self-assessments are evaluated and corrective actions tracked through completion. Overall results of these self-assessments found that the WVDP continued to implement and in some cases improve the quality of the environmental protection and monitoring program.